

# ***A Brief Overview of Geothermal Energy***

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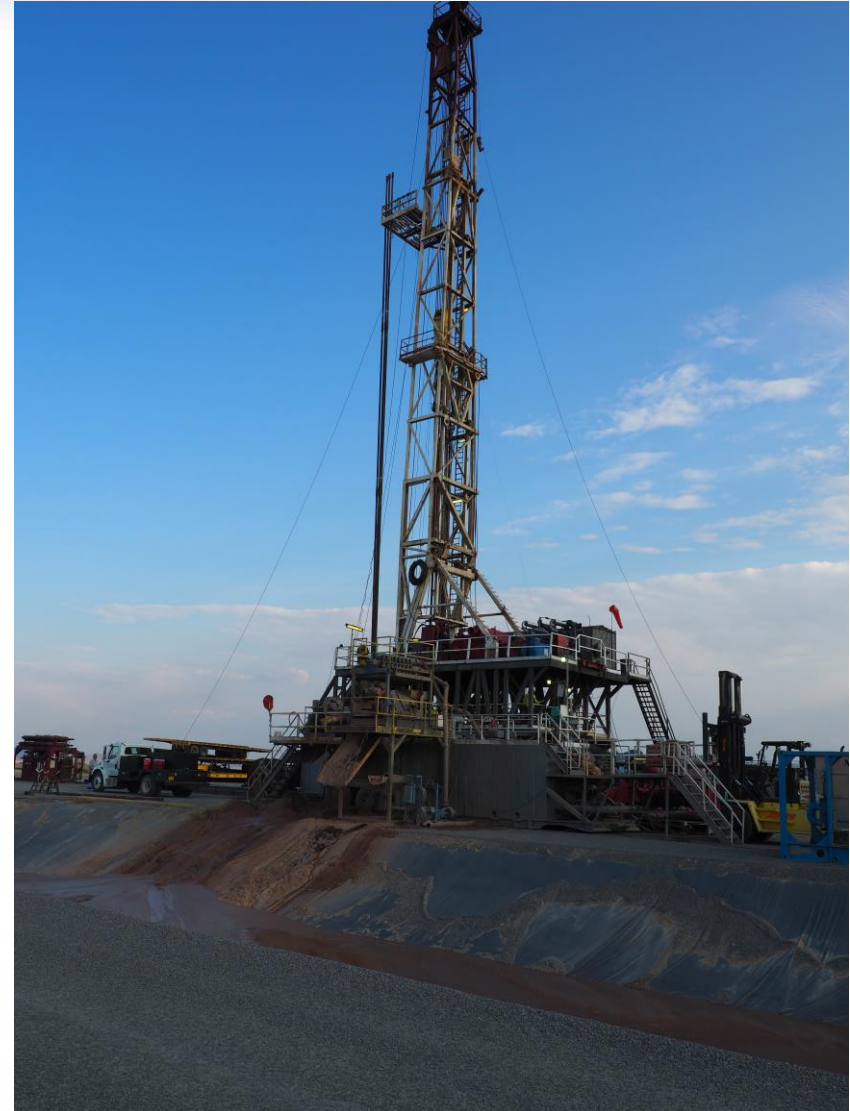
Geothermal Design Challenge  
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[www.inl.gov](http://www.inl.gov)



# Outline

- Why is geothermal energy important?
- Resource Types
  - Hydrothermal
  - EGS
  - Direct Use
- Where are resources located?
- What is the resource base?
- An idea for GDC

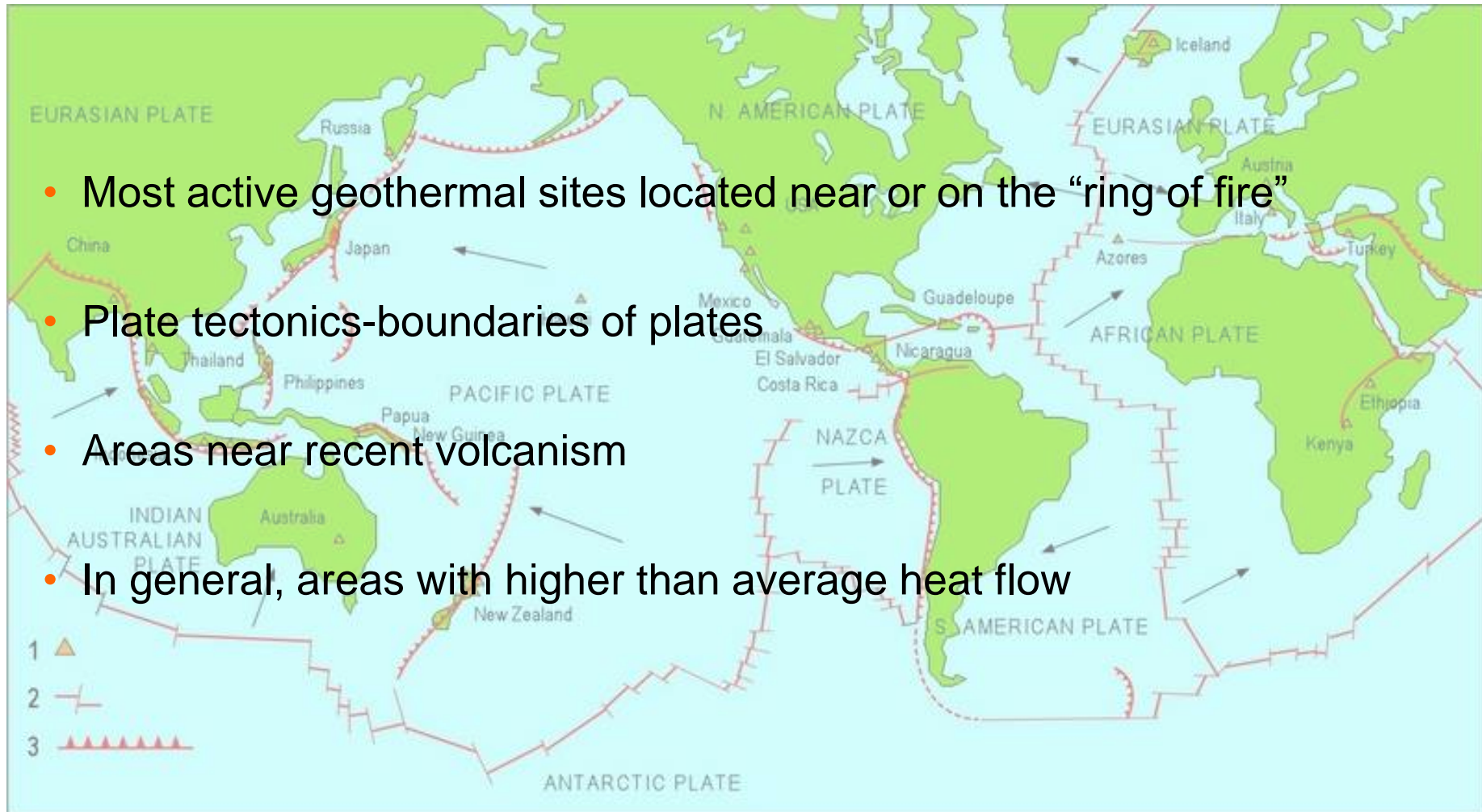


# ***Why is Geothermal Energy Important?***

- It's renewable...
  - “Inexhaustible” supply of heat from earth's core
  - ~30 year operational life of powerplant, 100 year heat recharge
- It's clean...
  - Nearly 0 GHG emissions
  - Typical geothermal plant <1% of CO<sub>2</sub> emission of typical coal plant
- It's available 24/7...
  - No intermittency issues like those with solar, wind, etc
  - Firming or baseload in conjunction with intermittent renewables
- It's abundant and has large potential for expansion...
  - Current world capacity ~ 15 GW
  - US potential reportedly 40 GW with current technology
  - US potential reportedly 100-1,200 GW in next 50 years with EGS

## Where are the resources?

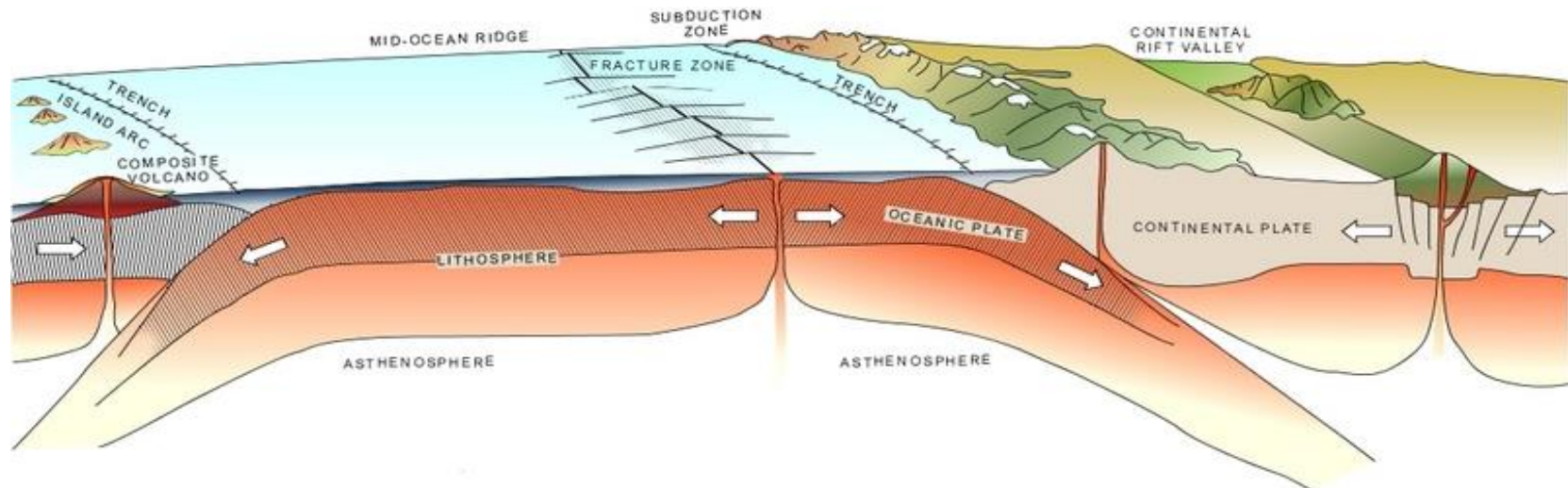
- Most active geothermal sites located near or on the “ring of fire”
- Plate tectonics-boundaries of plates
- Areas near recent volcanism
- In general, areas with higher than average heat flow



From Dickson and Fanelli, 2004

## *Why are they where they are?*

- Plate margins correspond to weak, densely fractured zones
  - Volcanoes
  - High heat flow
- MOR settings-Iceland [plate boundary]
- Subduction zones-Philippines [plate boundary]
- Hot Spots-Hawaii, Idaho (Yellowstone) [recent volcanism]





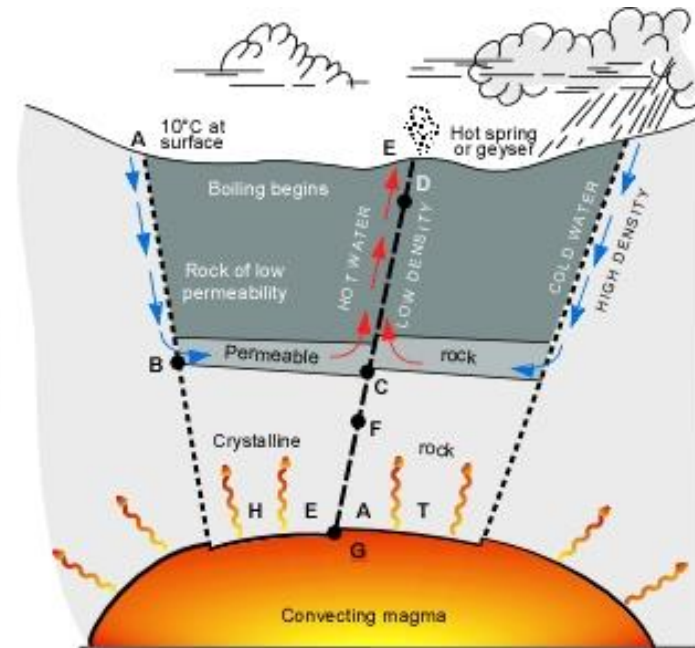
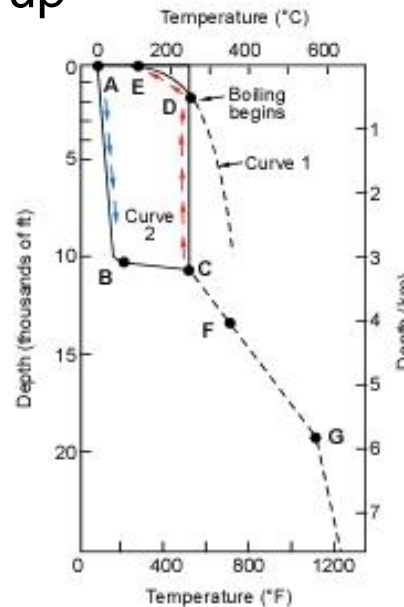
# *Types of Geothermal Reservoirs*

- Hydrothermal
  - Rely on existing permeability
  - Drill wells, extract (and inject) fluids
- Enhanced Geothermal Systems (EGS)
  - Formerly “hot-dry rock”
  - Take steps to create permeability
  - Largely experimental
- Generally categorize as
  - Dry steam
  - Wet steam (or flash)
  - Binary systems
- Direct Use Geothermal
  - Lower temperatures
  - Use heat directly
  - Industrial or residential



# Hydrothermal Systems

- Geothermal system is made up of 3 general components
  - Heat source
  - A reservoir
  - A heat transfer fluid
- Convection and conduction control from below
- Permeability necessary



From IGA, 2004

## ***Examples of Hydrothermal Systems***

- The Geysers, in Northern California
  - 1<sup>st</sup> US plant, circa 1960
  - Largest in the world
  - Dry steam
- The Hellisheidi Field, Iceland
  - Outside Reykjavik
  - Combined Cycle
  - Individual wells produce up to 20 MW
  - Flash steam





# ***Enhanced Geothermal Systems***

- Geothermal reservoir that does not require natural convective hydrothermal resources
  - Can move away from the “ring of fire”
  - Site anywhere have rock at sufficient temperature at reasonable depth
- Formerly know as “hot-dry rock” systems
- FORGE Laboratory in Utah
- EGS systems currently being developed and tested in France, Australia, Japan, Germany, the US and Switzerland
- Enormous potential resource

# How EGS works

- Must have the heat source
- May or may not have the fluid
- Usually have no reservoir....it must be created, but how?
- Reservoirs created by stimulation of the subsurface
  - Break the rock via fracturing or reactivation of shear fractures
  - Drill a well and inject a fluid at very high pressures
  - Map resulting fractures and drill a second well

## Enhanced Geothermal Systems (EGS) Explained

The geothermal reservoir and its wells comprise an EGS system - Naturally heated, but impermeable rock (1) is fractured to create the reservoir, enabling water to flow through production wells (2) as one leg of a circulation loop, passing through a heat exchanger at the surface where power is generated (3), and returning to the reservoir through injection wells (4).

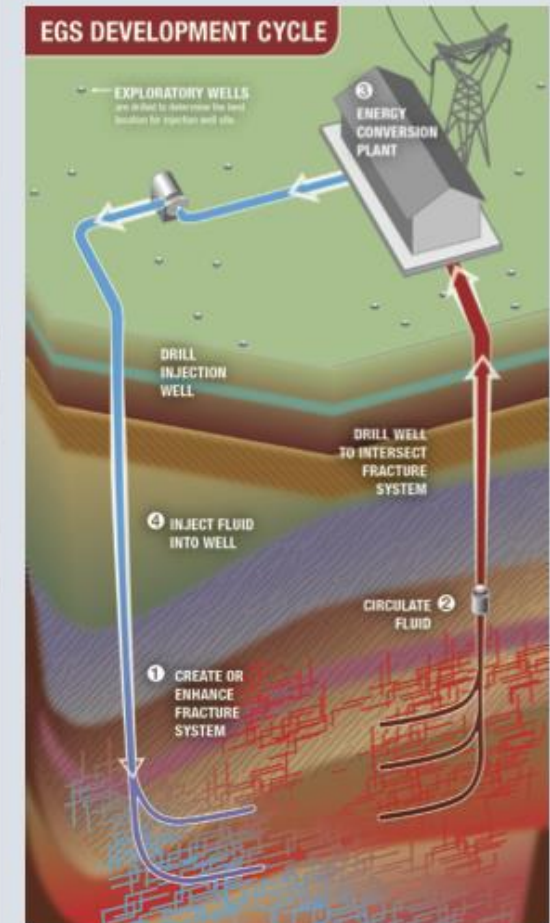
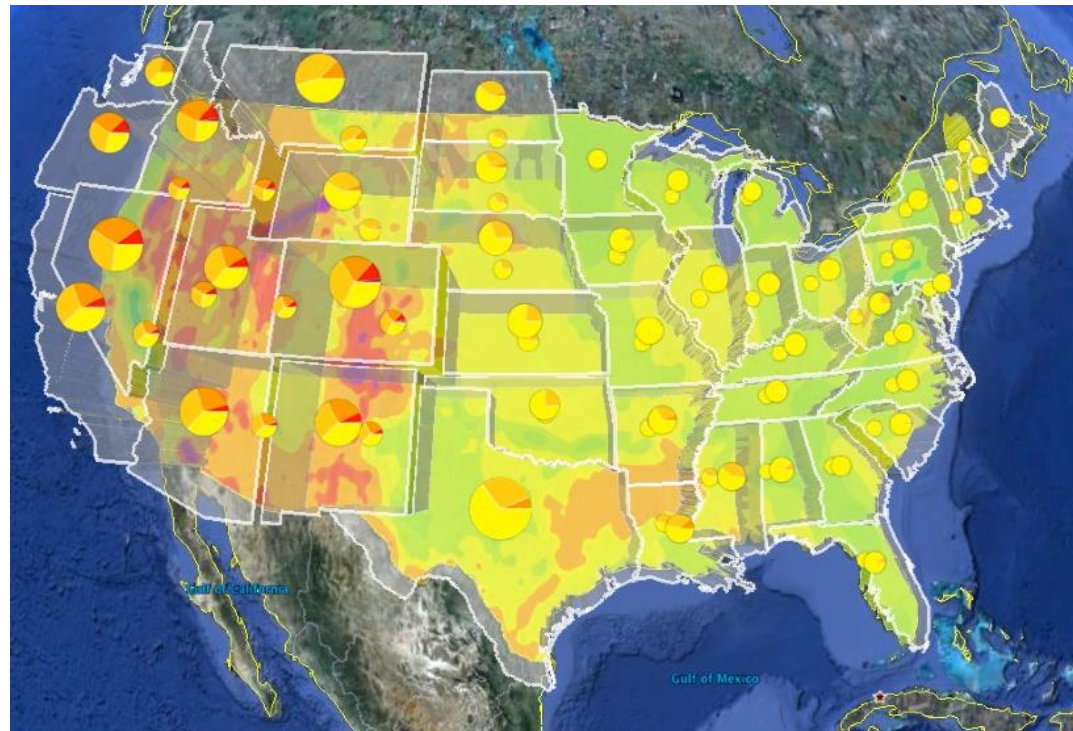


Figure 1.2. Enhanced Geothermal Systems

## ***EGS Resource Base Estimates***

- US estimates developed in 2006  
MIT report
- 100 GW could reportedly be installed by 2050
  - 100 GW = 100,000 MW = power 100,000,000 homes!
  - Estimates vary widely
  - With significant R&D investment
- Number of high-grade areas identified
  - Snake River Plain
  - Great Basin
  - Oregon Cascades
  - Salton Sea
  - Southern Rockies
  - Clear Lake Volcanic Field





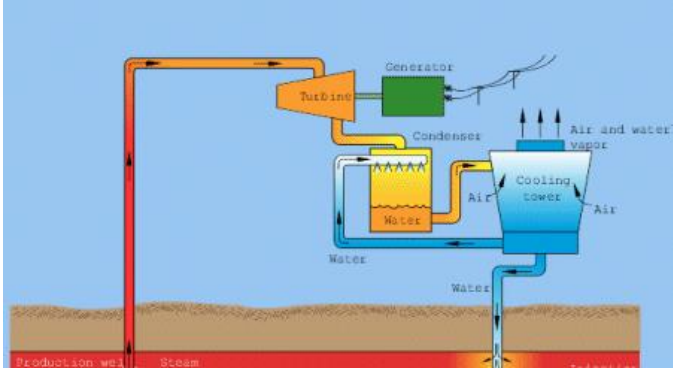
# ***EGS Field Laboratory—FORGE***

- The FORGE site is being designed as an EGS laboratory that will allow investigators to interactively develop and optimize EGS technologies
- Site near Milford Utah
- Drilled, completed and tested exploration well to 7536 ft
- Planning first “full-sized” well now, with target to drill this summer

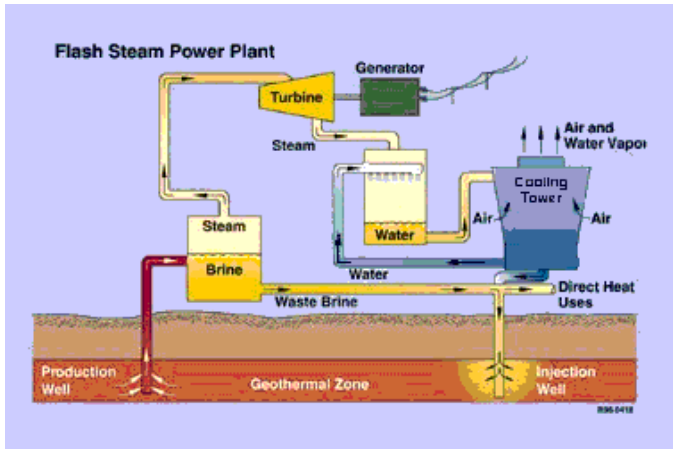




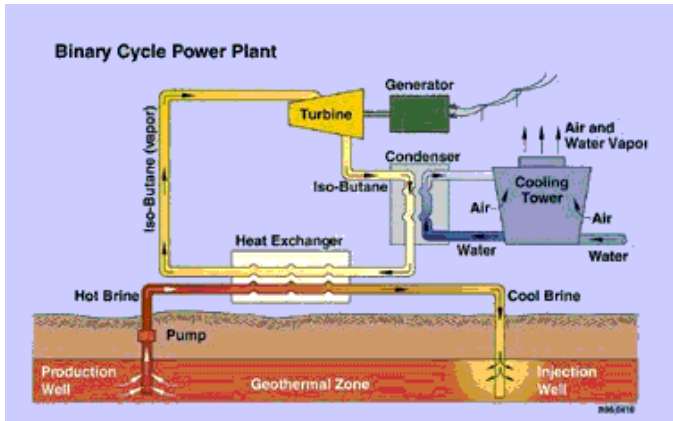
# Power Plant Types



- Dry Steam



- Flash (or wet) Steam

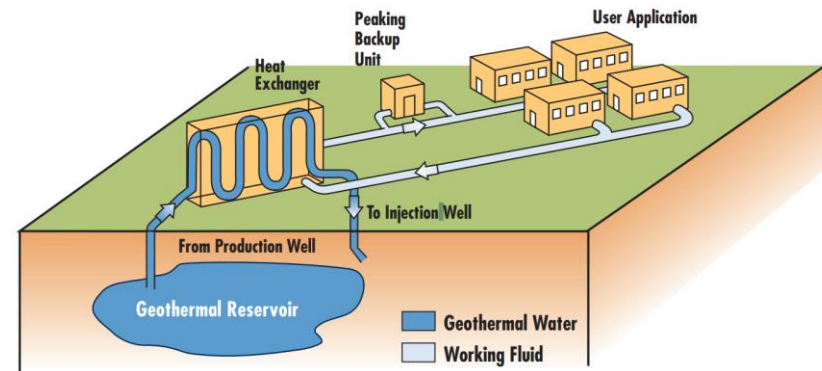


- Binary



## Direct Use

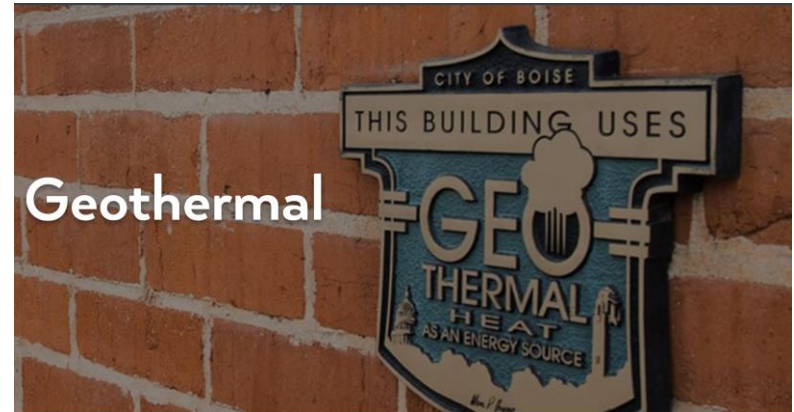
- Geothermal heat can also be used directly, in numerous applications
- Low-temperature geothermal resources exist throughout the United States
  - Mostly in the West, but eastern locations being actively explored
- Applications include
  - District heating
  - Agriculture (greenhouse, drying)
  - Aquaculture (fish farming)
  - Even have alligator farms in Idaho!



From NREL, 2004

## ***Direct Use Example – Boise ID District Heating***

- Boise has the world's longest running geothermal district heating system, started operation in 1892
- Many parts of the city supplied with heat, and system is undergoing an expansion
- Idaho's Capitol Building is heated on the system
- Naturally heated 177° F water through a network of pipes that warmed more than 6 million square feet of building space



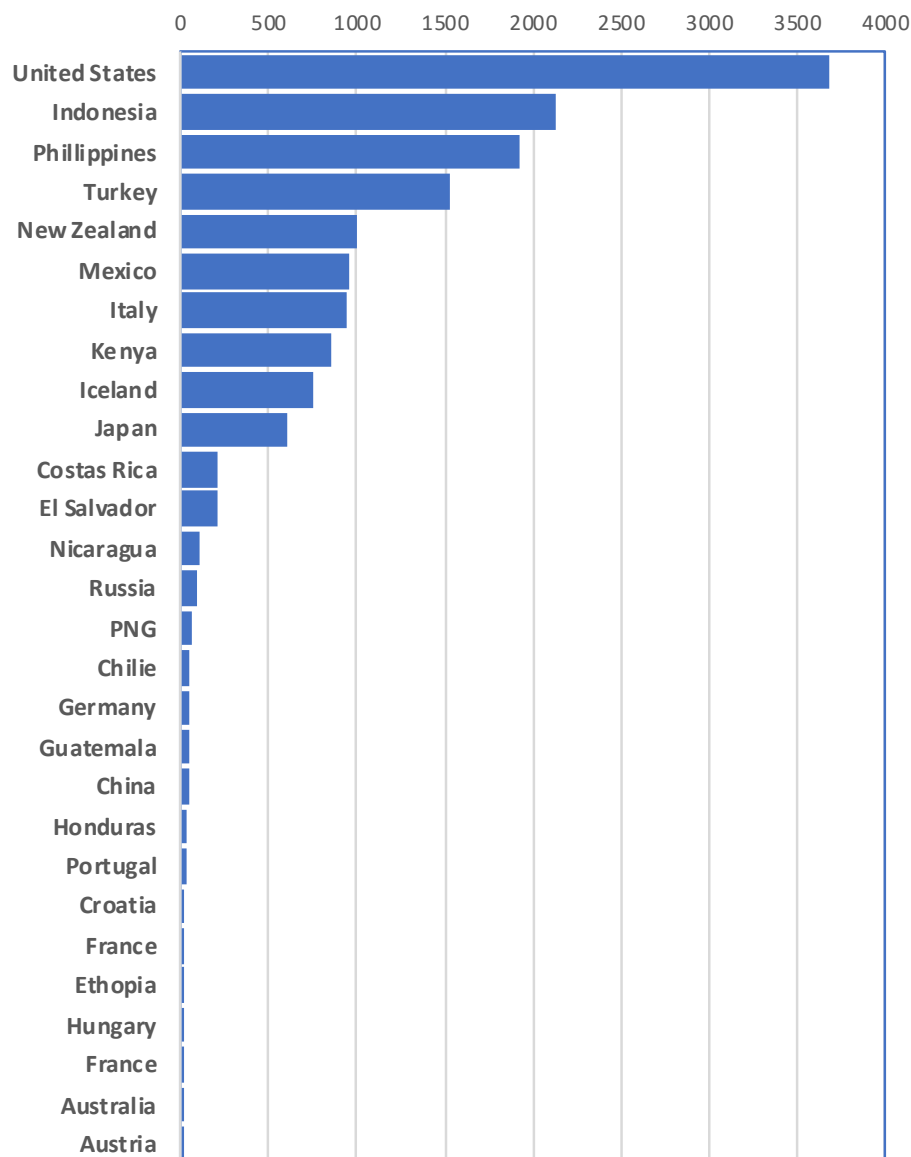
From City of Boise and State of Idaho



# Worldwide Installed Generation Capacity

- Worldwide installed capacity is ~15,300 MW
  - 27 countries
  - Provide electricity for over 50 million people
  - Grew by ~5000 MW in last decade
- US has highest capacity
  - 5 nations producing over 1 GW
- Large generation share in some nations
  - Iceland
  - Philippines
- US has highest generation, but low overall percentage of total generation

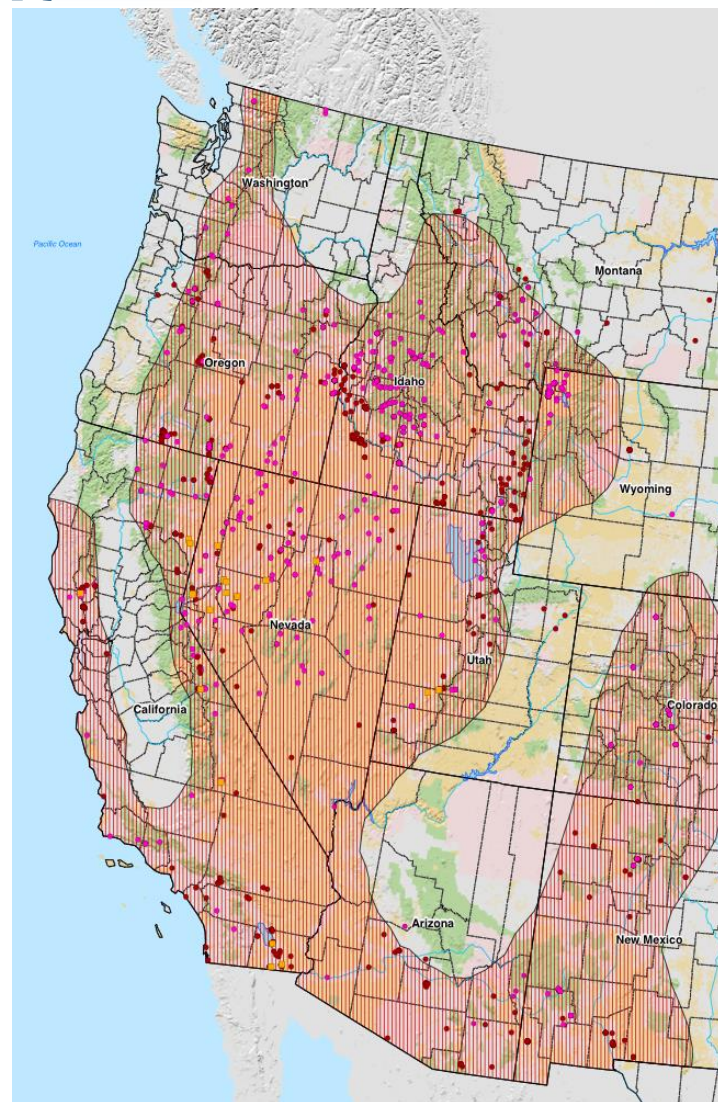
Geothermal Generation in MW





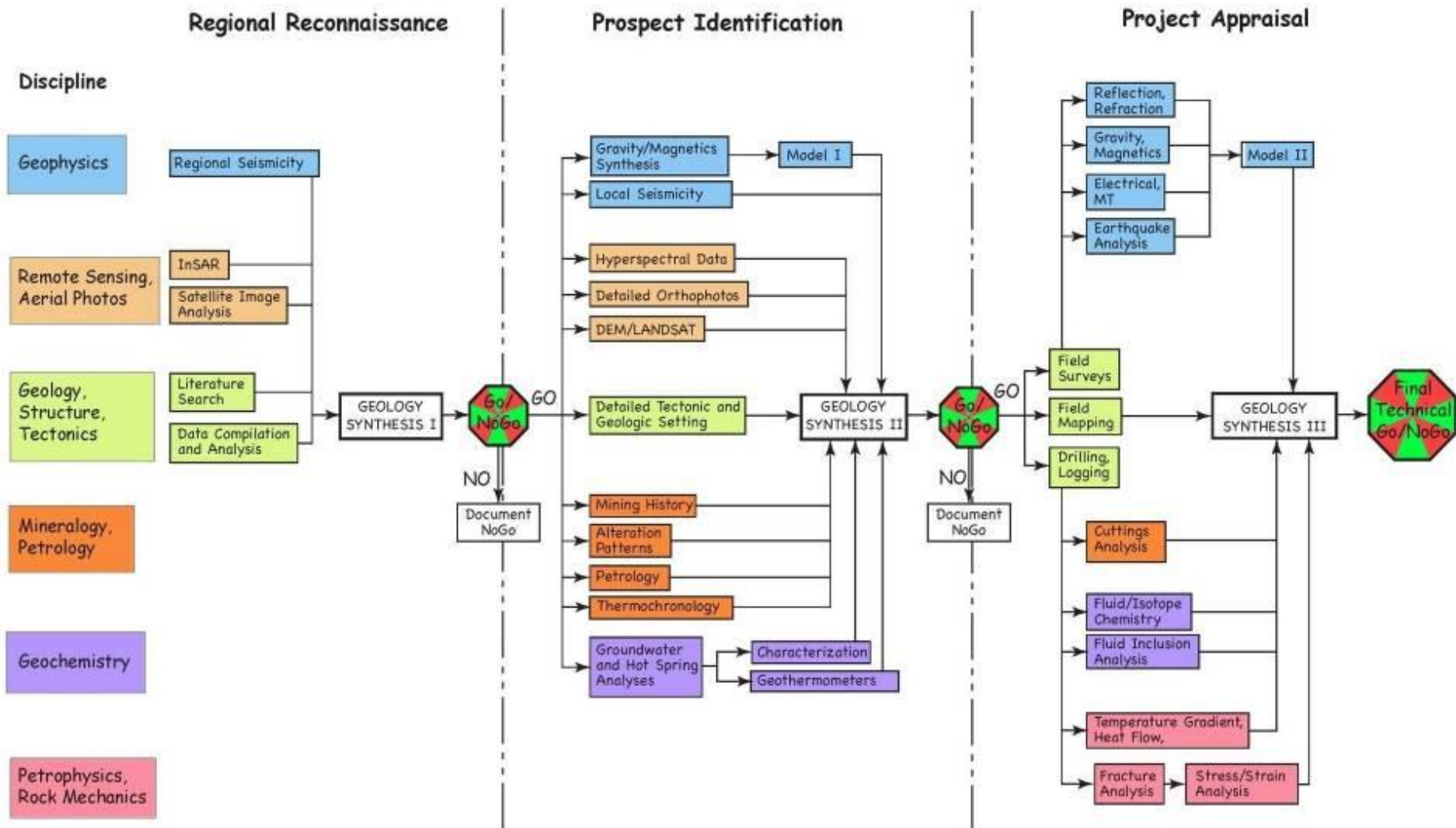
# US Hydrothermal Development

- Mostly in the West
  - 9 Western States contribute majority of US supply
  - Most recent volcanism and mountain building
- California largest producer, by far
  - Geysers and Imperial Valley
- Basin and Range Province
  - Nevada, Utah, Idaho
- Hawaii, Alaska
- Hawaii Big Island had large percentage geothermal



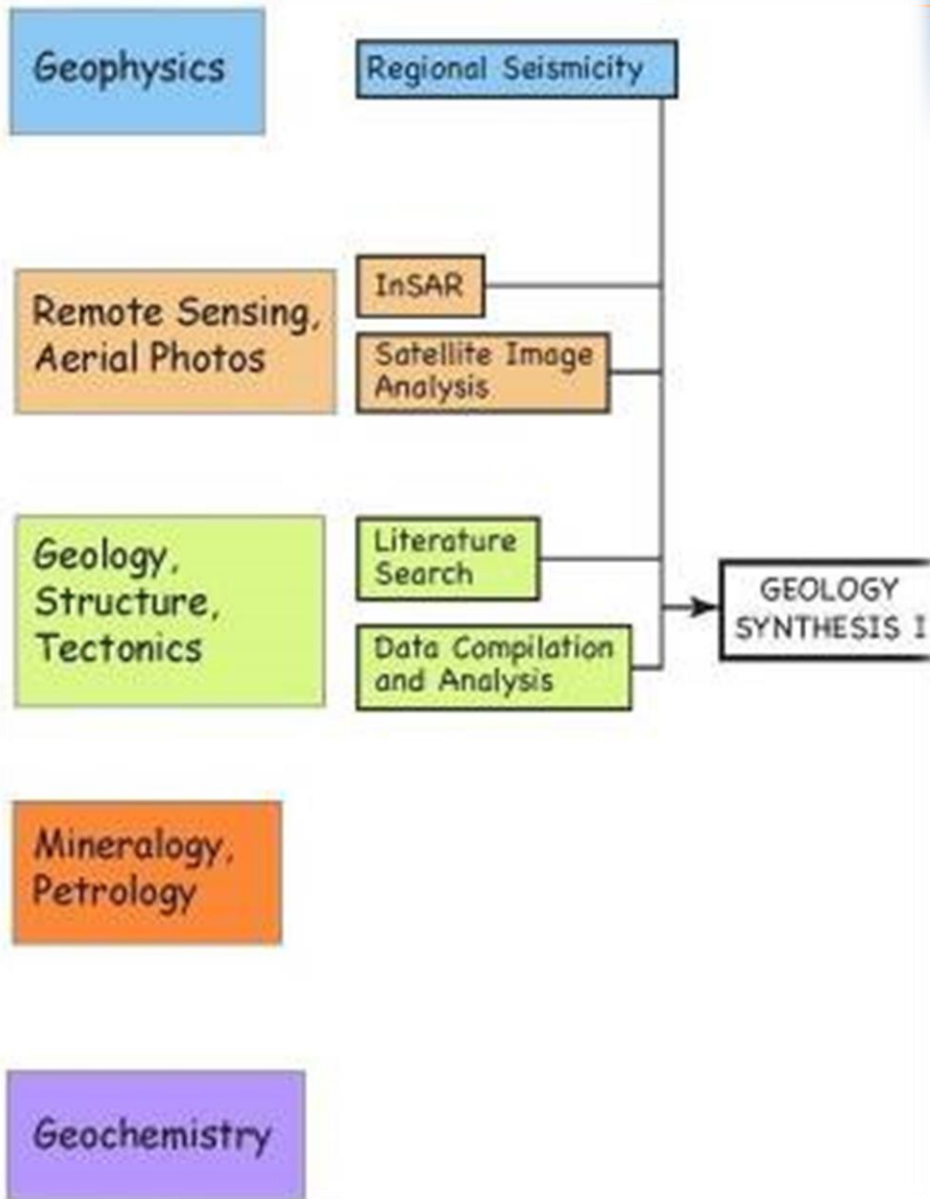
# How Do You Find Geothermal Resources?

## Steps to Delineating a Geothermal Resource



## ***Stage 1 Information Often Compiled Includes:***

- Local and regional geologic maps
- Geophysical surveys (gravity, aeromagnetic, seismic, electrical)
- Well data (lithology, borehole geophysics, temperature logs, bottom-hole temperatures, etc.)
- Geochemistry of springs and well waters (aquifers)
- Remote sensing imagery (aerial photographs, satellite images, satellite data)
- Quaternary/Holocene faults
- Crustal strain rates (geologic and GPS)
- Recent volcanism
- Literature searches for additional relevant data



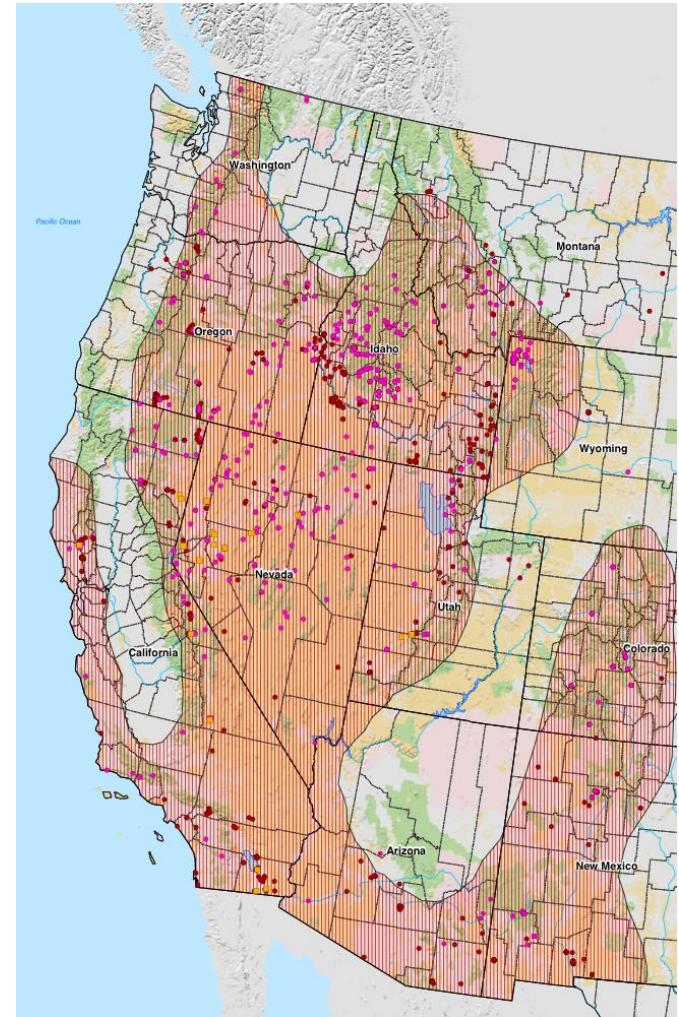
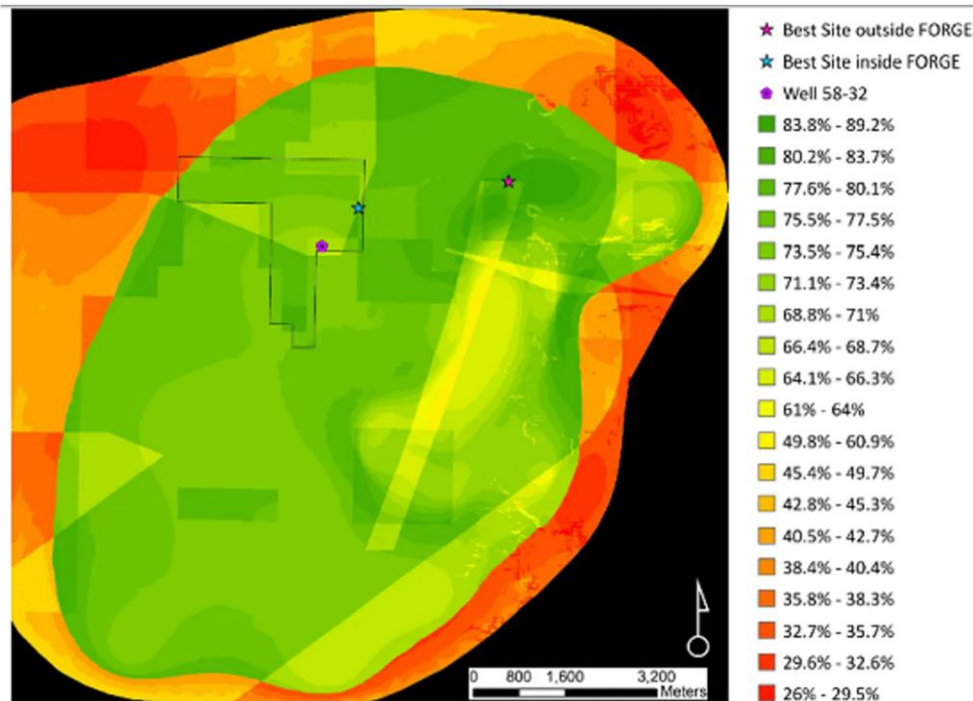
## ***Stage 1 Compilation and Synthesis***

- Compile and synthesize all available relevant information.
- Assemble relevant information from diverse sources on maps and in ways that enable direct comparison and discovery of new relationships.
- Synthesis of diverse data to generate questions, ideas, and concepts.

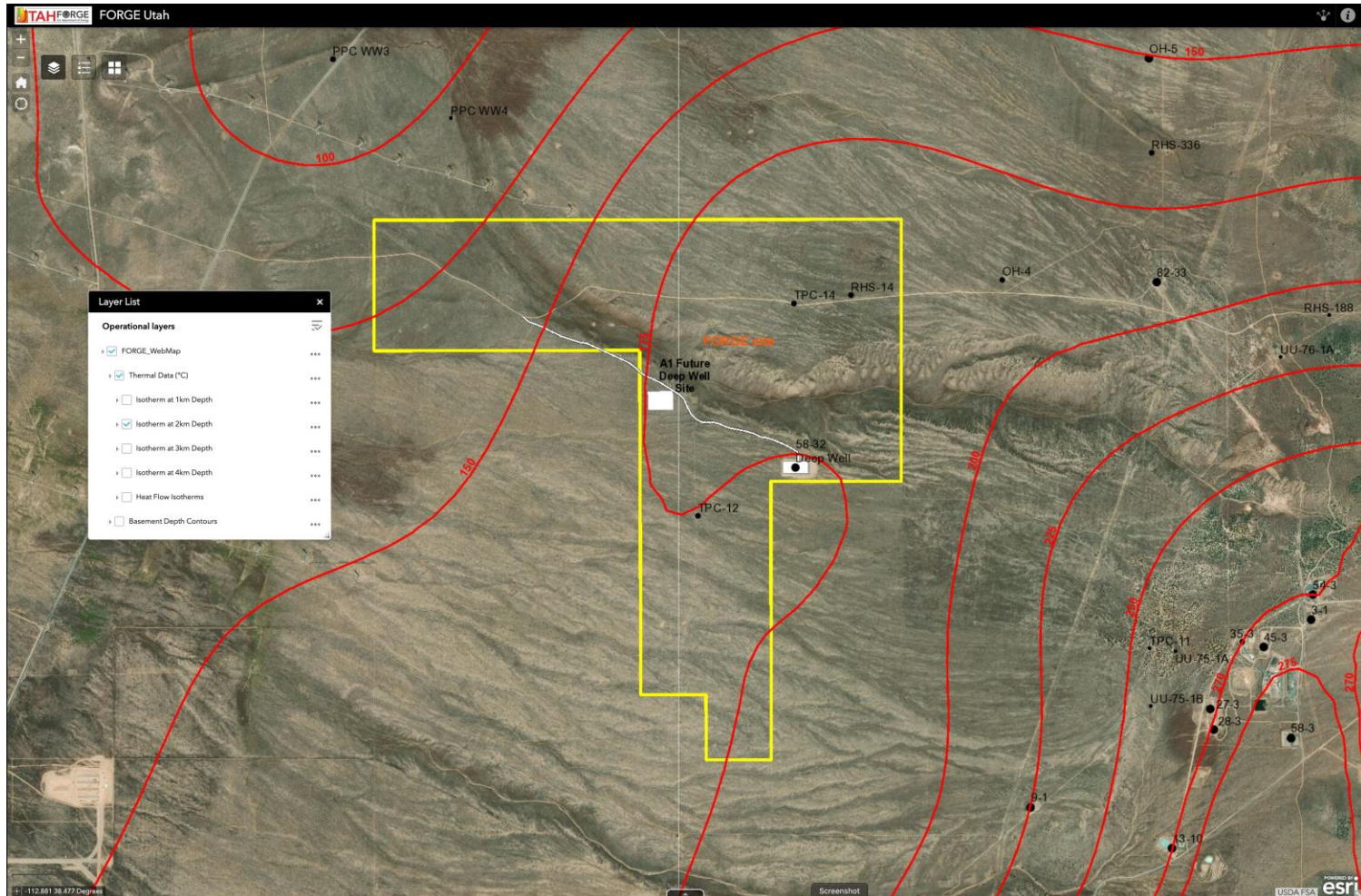


# Application of Geographic Information Systems

ArcGIS



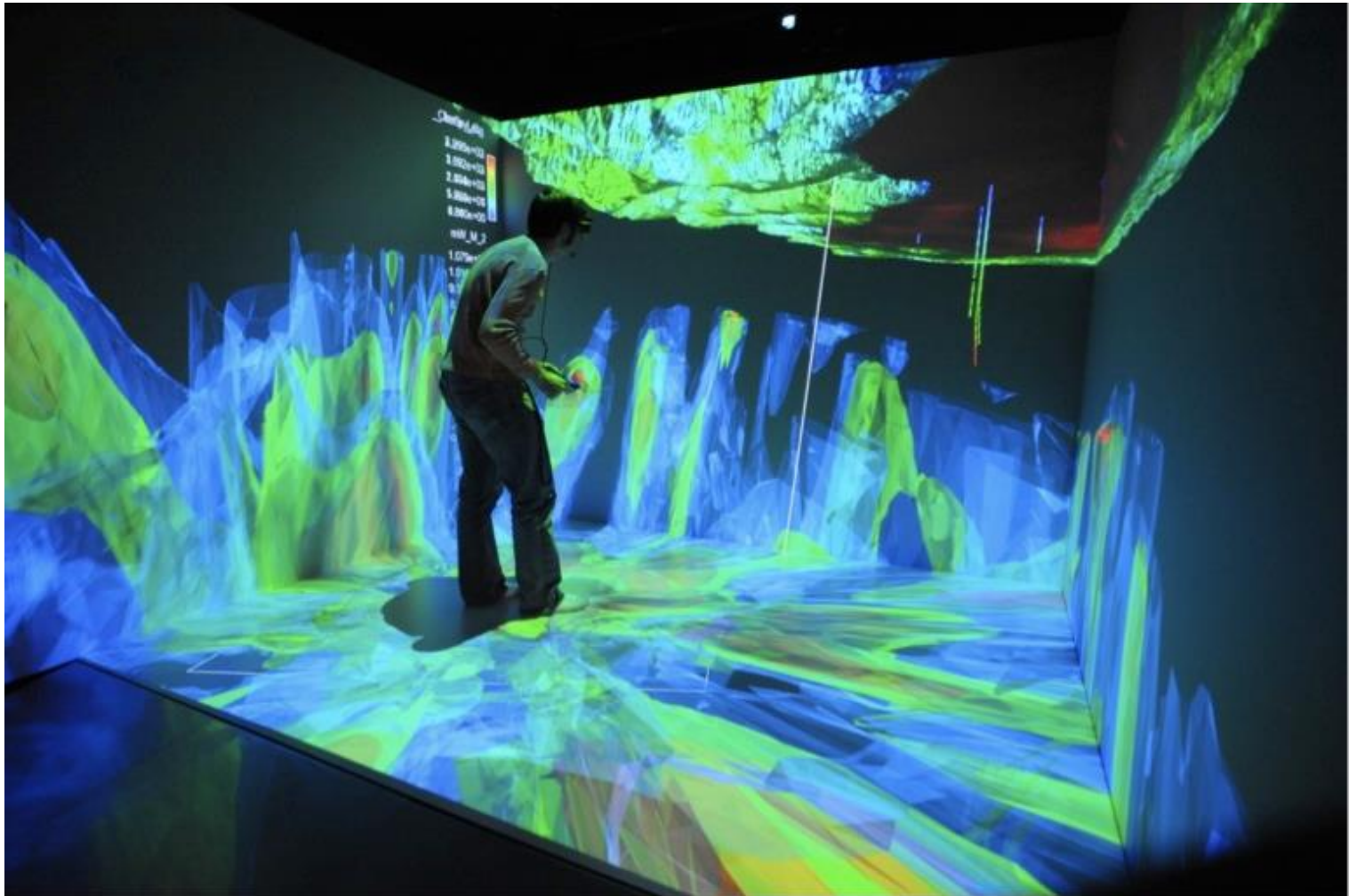
# Application of Geographic Information Systems



<https://geology.utah.gov/apps/jay/forge/>



# *Application of Geographic Information Systems*



## ***Summary Points***

- Geothermal is a clean, truly renewable energy source
- Three general kinds of reservoirs (and power plants)
- US leads the world in generating capacity
- GIS is a powerful of often used tool for geothermal exploration





**Questions? E-mail [geothermalchallenge@inl.gov](mailto:geothermalchallenge@inl.gov)**